

TABLE OF CONTENTS

1.	INTRODUCTION	1
2.	BACKGROUND	2
3.	AQUIFER CHARACTERISTICS.....	3
3.1	Depth to Groundwater and Groundwater Flow	3
3.1.1	Depth to Groundwater.....	3
3.1.2	Occurrence of Saturated Basin Fill	3
3.1.3	Water Level Trends.....	4
3.1.4	Groundwater Flow Direction and Hydraulic Gradient	4
3.1.5	Recharge	5
3.2	Nearest Downgradient Well.....	5
3.3	Hydraulic Parameters.....	5
3.3.1	Pumping Tests.....	5
3.3.2	Transmissivity and Hydraulic Conductivity	6
3.3.3	Storativity.....	6
3.3.4	Porosity	6
4.	CHANGES IN PRESSURE OF INJECTED FLUID	9
5.	NATIVE FLUID DISPLACEMENT	10
6.	DIRECTION OF MOVEMENT OF INJECTED FLUID	11

TABLES

N-1	Porosity Calculations from NSH-019 Aquifer Testing
N-2	Porosity from Gamma-Gamma Logs

FIGURES

N-1	Depths to Groundwater, June 2015
N-2	Potentiometric Surface in Relation to Bedrock
N-3	Hydrology Study Boreholes and Wells
N-4	Bedrock Elevation Contours
N-5	Groundwater Level Hydrographs for Select Wells
N-6	Potentiometric Surface Map, June 2015
N-7	Aquifer Testing Locations

1. INTRODUCTION

This Attachment was prepared in support of Excelsior Mining Arizona, Inc.'s (Excelsior's) Underground Injection Control (UIC) Permit application to the United States Environmental Protection Agency (USEPA). Excelsior is applying for an area Class III UIC permit to install a wellfield for in-situ recovery (ISR) of copper at the Gunnison Copper Project (Project), located in Cochise County, Arizona.

This attachment includes a discussion on the changes that are expected to occur in the injected fluids between injection and recovery, in particular, changes in pressure, native fluid displacement, and the direction of movement of injection fluid.

The information presented in this Attachment relies extensively on the text, tables, and figures of the Groundwater Model Report which is included in Attachment A-2.

2. BACKGROUND

The ISR wellfield will consist of an array of Class III injection and recovery wells. Raffinate from the solvent extraction/electrowinning (SX-EW) plant will be acidified and pumped to the ISR wellfield through a network of process piping to an array of injection wells. Extraction wells interspaced with the injection wells will be pumped to create a hydraulic gradient that promotes flow of the leach solution through the mineralized formation. Acid-soluble copper will be drawn into solution as it migrates toward the extraction wells. The pregnant leach solution (PLS) recovered from the extraction wells will be collected in the PLS pond by a network of process piping. Copper will be recovered from the PLS through the SX-EW process.

The top of the injection zone will be a minimum of 20 feet below the top of bedrock, and the bottom of the injection zone will be the top of the sulfide zone. The thickness of the injection zone will range from 50 to 1250 feet, but over most of the Project area it will generally be between 400 and 800 feet in thickness. At maximum production, approximately 28,000 gallons per minute (gpm) of PLS will be extracted from the recovery wells and sent to the SX-EW plant.

Hydraulic control and observation wells will be distributed around the wellfield, primarily the eastern, southern and northern boundaries, to maintain hydraulic control of the leach solution by creating an inward hydraulic gradient. Observation well pairs will be located outside of the hydraulic control wells and will be used for measuring the static water levels to demonstrate inward gradients.

3. AQUIFER CHARACTERISTICS

In order to understand changes in pressure, native fluid displacement, and the direction of movement of injection fluids, a conceptual understanding of the aquifer characteristics is necessary. The text below is from the Hydrogeologic Study (Section 5) of Excelsior's Aquifer Protection Permit application that was submitted to the Arizona Department of Environmental Quality on January 13, 2016.

3.1 Depth to Groundwater and Groundwater Flow

3.1.1 Depth to Groundwater

Groundwater levels are discussed in Section 2.5.4 of Attachment A-2, and a complete groundwater database used for the groundwater flow model is provided as an exhibit in Attachment A-2.

A depth-to-groundwater map, based on a water level sweep conducted in June 2015, is presented on Figure N-1. Depths to water ranged from 244 feet below land surface at exploration drill hole NSD-030 in the northwest part of the Project, to 655 feet below land surface at hydrology study well NSH-013 near the middle of the orebody.

Figure N-2 shows the relationship of the potentiometric surface to the bedrock surface. Positive numbers indicate that the potentiometric is deeper than the bedrock-basin fill contact. Negative numbers indicate the potentiometric surface is above the bedrock-basin fill contact. However, most negative numbers are indicative of confined conditions, not saturated basin fill (which is discussed below).

3.1.2 Occurrence of Saturated Basin Fill

Basin fill overlying the ISR wellfield is generally unsaturated. The absence of saturated basin fill within the proposed wellfield was documented by Haley & Aldrich during their hydrogeologic investigation of the Project (Attachment S-2). Haley & Aldrich oversaw and documented the drilling and installation of 21 hydrogeologic wells and 5 piezometers in 2014-2015 (Figure N-3). Saturated basin fill was not observed in any of the boreholes near and within the proposed wellfield during this drilling campaign. Groundwater was encountered in bedrock fractures, often well below the basin fill-bedrock contact. After well completion in the bedrock, groundwater rose up into the cased section within the basin fill in some of the wells (NSH-014B, NSH-016, NSH-009). These groundwater levels represent a potentiometric surface, indicating confined conditions within the bedrock aquifer.

Thin, isolated occurrences of saturated basin fill have been identified at only two locations with the Area of Review (AOR) that is being proposed in the UIC permit application:

- NSH-006. This was one of six wells (NSH-001-NSH-006) drilled during a 2011-2012 drilling program to characterize the hydrogeology of the Project. The Haley & Aldrich report (Attachment S-2) indicates it had 40 feet of saturated basin fill; recent water levels indicate approximately 30 feet of saturation at this well.
- NSD-020. This well was an exploration borehole drilled in 2011 that was not drilled into bedrock. The well had 30 feet of saturated basin fill at the time of installation.

Both NSH-006 and NSD-020 are within an isolated low spot on the bedrock surface that appears to be constrained by the 4,200-foot bedrock surface contour (Figure N-4).

Excelsior will not request an aquifer exemption for the basin fill in their UIC permit application because it does not meet the definition of an underground source of drinking water (USDW) according to 40 Code of Federal Regulations (CFR) §144.3. Specifically, the basin fill does not contain “sufficient quantity of groundwater to supply a public water system.”

3.1.3 Water Level Trends

Figure N-5 presents hydrographs of selected groundwater level measuring locations. The measuring sites represent a geographic distribution around the Project area and have relatively complete historical water level records. The locations selected are shown on Figure N-1. Water levels at three of the measuring sites, CS-15, CS-12, and NSD-15 have been stable over their measurement history. The water level at NSD-028 has dropped 20 feet since the end of 2012.

Figure 12 in Attachment A-2 is a hydrograph for the Dragoon Water Company Well No. 1, which is the only well in the area with an adequate dataset to construct a long-term hydrograph. The water level data show that the water levels rose during periods of increasing rainfall (1950 to 1990), and fell during periods of drought (1990 to 2015).

3.1.4 Groundwater Flow Direction and Hydraulic Gradient

Figure N-6 is a regional potentiometric surface map based on water levels summarized in Table 6 in Attachment A-2. As shown on Figure N-6, the direction of groundwater flow is from west to east. Hydraulic gradients vary considerably. East of the 4200-foot contour the gradient is relatively low. West of the Project, gradients are higher (approximately 0.15), which is consistent with the relatively unfractured nature of the Texas Canyon Quartz Monzonite. In the area of the deposit, the hydraulic gradient is much lower (0.01 and lower), presumably due to the greater degree of fracturing, and thus higher permeability, associated with skarn mineralization.

3.1.5 Recharge

According to the site conceptual model (as further discussed in Attachment A-2), groundwater is recharged from precipitation in the higher elevation areas. Recharge also occurs in the washes and drainages which carry surface flows eastward out of the basin. The recharged water enters either the bedrock in the upland areas, or the basin fill aquifer at lower elevations. Groundwater then flows eastward to the basin exit points at Walnut Gap and Big Draw.

Groundwater flow is parallel with surface flows, and the groundwater divide generally follows the surface water divide between Walnut Gap and Big Draw.

As described in Attachment A-2, recharge volumes were estimated based on the area of the surface drainage basins and an average value of 12.5 inches of precipitation per year. It was assumed that approximately 3% of available precipitation recharges the aquifer, based on similar modeling studies. Table 4 in Attachment A-2 provides the estimates of recharge volume.

3.2 Nearest Downgradient Well

The area downgradient of the Project includes Section 32 of Township 15 South, Range 23 East, and Section 5 of Township 16 South, Range 23 East. There are no non-Excelsior wells registered in either section, based on a review of Arizona Department of Water Resources' on-line well registry database on November 12, 2015. More information is provided in Attachment B.

3.3 Hydraulic Parameters

3.3.1 Pumping Tests

Excelsior conducted constant-rate pumping and recovery tests at 24 wells. A report documenting the tests is provided in Attachment A-3. Most of the tests were conducted on the wells screened in bedrock. One test was conducted at a well screened in the overlying basin fill (NSH-006). The saturated interval in the well was only 33 feet, and the maximum drawdown during a 24-hour test was less than one-half foot at a pumping rate of 3 gpm.

The locations of the aquifer tests (pumping wells) are shown on Figure N-7. Well NSH-2 was tested in July 2011. Wells NSH-3 through NSH-6 were tested in 2012. Wells NSH-007 through NSH-028 were tested in 2015. A table summarizing the results of the pumping tests is provided as Table 3 in Attachment A-3.

3.3.2 Transmissivity and Hydraulic Conductivity

According to the aquifer testing results (Attachment A-3), the oxide orebody has an average hydraulic conductivity of 1.1 feet per day (ft/day). The hydraulic conductivities determined at the Project by aquifer testing ranged from 0.01 to 9.8 ft/day. Variation is likely controlled by intensive faulting and associated heterogeneities. Analyses of drawdown data in the orebody indicate that most wells are connected to faults.

3.3.3 Storativity

Storage coefficients (as discussed in more detail in Attachment A-3) indicate that the bedrock aquifer is confined. Overall, the tested wells demonstrate good connectivity through propagation of significant drawdowns over distances of up to 1000 feet. Pumping rates at individual test wells varied from 2 to 170 gpm. Even the low-yield wells demonstrated long-distance hydraulic connectivity with observation wells. Storage coefficients calculated from tests conducted at the two wells completed in the deeper sulfide zone, NSH-014B and NSH-025, are two orders of magnitude lower than storage coefficients calculated from tests conducted in the wells completed in the oxide zone.

3.3.4 Porosity

Porosity is a measure of the total void space within porous material, expressed as a percentage of the total volume of the material. Effective porosity represents the volume of interconnected void space and is also expressed as a percentage of the total volume of material. In an unconfined aquifer, effective porosity in the saturated zone is essentially equivalent to specific yield, and total porosity is equal to specific yield plus specific retention.

Excelsior estimated the porosity of bedrock at the Project by reviewing published values in the literature, analyzing pumping test results, and conducting gamma-gamma density logging of the NSH- series boreholes. No single porosity value was chosen for the site. The porosity values discussed in the sections below were considered during model construction, and porosity values consistent with these values were used in the groundwater flow model and the rinsing strategy. Porosity values are discussed further in the sections below.

3.3.4.1 Literature Review

Estimates of porosity for various rock types are available in published literature. Davis and DeWiest (1966) noted that “fresh metamorphic and plutonic igneous rocks have porosities of less than 3 per cent and most commonly less than 1 per cent”; they added that “appreciable porosities” develop from fracturing and weathering. They also stated that “even though numerous solution cavities may form in rocks such as marble . . . the pore space of large volumes of rock is probably not greater than 2 to 5 per cent.” This is consistent with Freeze and Cherry

(1979), who reported that porosity values for fractured crystalline rock range from 0 to 10%. Kim and others (2015) measured bedrock porosity values ranging from 0.80% to 8.40% and averaging 3.99% for a skarn deposit in Korea. Because the Gunnison orebody is also a skarn deposit, its porosity is likely to be similar.

3.3.4.2 Pumping Test Analysis

As discussed in Attachment A-3, Excelsior conducted multi-well aquifer testing at numerous locations around the Project area. These aquifer tests helped characterize the parameters governing the ability of the bedrock to store and transmit water.

Because groundwater at the Project exhibits properties indicative of confined conditions, the storativity values obtained from commonly used aquifer test solution methods do not represent specific yield and are not useful for estimating porosity. As an alternative, in an effort to generate a rough estimate of porosity, Excelsior applied the Ramsahoye and Lang (1961) method to the test results. This method involves calculating the volume of dewatered material in the cone of depression around the pumping well and comparing it to the total volume of discharged water. The following equation is used:

$$S_y = (Q * t) / (7.48 * V) \quad N.1$$

where S_y is specific yield, Q is the average pumping rate in gallons per day, t is the number of days since pumping began, 7.48 is a conversion factor between gallons and cubic feet, and V is the volume of dewatered material in cubic feet. V is calculated from the pumping rate (Q), horizontal distance of the observation well from the pumping well in feet (r), transmissivity (T) of the aquifer in gallons per day per foot, and drawdown at the observation well in feet (s):

$$V = (Q * r^2 * \exp((4pTs)/Q)) / (4 * T) \quad N.2$$

Results of the analysis are shown on Table N-1 for a 5-day constant-rate pumping test conducted at Well NSH-019. Water levels in nine observation wells¹, ranging in distance from 77 feet to 1,493 feet from the pumping well, were monitored during the test. Specific yield (and thus porosity) were roughly estimated by applying the Ramsahoye and Lang (1961) method to the drawdown recorded at each of the observation wells. The estimated values of specific yield ranged from 0.1% at the farthest observation well to 1.6% at the nearest observation well.

Two key assumptions of the Ramsahoye and Lang (1961) method are that the aquifer is homogeneous and isotropic, and that “the cone of depression reaches approximate equilibrium form and is declining only very slowly.” Because of these assumptions, the validity of the results is highly sensitive to the duration of the test and the distance between the observation well and the pumping well. This sensitivity is apparent on Table N-1, with the results showing a strong inverse relationship between distance from the pumping well and calculated specific yield. With

¹ For purposes of the pumping test discussion, “observation wells” include coreholes that were used as water level monitoring locations during the tests.

the possible exception of the nearest observation well (NSM-008), the cone of depression did not appear to reach equilibrium at the end of the 5-day test. Since the specific yield in Equation N.1 is positively correlated with time, specific yields computed with drawdown measurements prior to reaching equilibrium were underestimated, particularly in the observation wells farthest from the pumping well. Therefore porosity (specific yield) estimations using the Ramsahoye and Lang (1961) method were deemed to underestimate porosity and the results of the analyses are considered minimum porosity values.

3.3.4.3 Gamma-Gamma Density Logs

Excelsior contracted with Colog of Lakewood, Colorado to conduct gamma-gamma density logging on hydrologic study wells NSH-008, NSH-009, NSH-013, NSH-015, NSH-023, NSH-026, and NSH-028. The geophysical logs are included in Attachment N-2. Porosity was calculated from the density logs using the following equation:

$$\text{Porosity (\%)} = [100 * (U - D) / (U - 1)] \quad N.3$$

where D is the measured long spaced density in grams per cubic centimeter (g/cc) at a given interval, U is the assumed density of unfractured rock (in g/cc), and 1 is the assumed density of fluid filling the pore space (in g/cc).

The value of U (2.63 g/cc) was obtained from the gamma-gamma density values measured on intervals that appeared to be unfractured on the acoustic televiewer and caliper logs. This approach is based on the premise that porosity is equal to zero (i.e., $U = D$) in intervals with no fractures visible on the acoustic televiewer or caliper logs. The lower density of the fractured intervals is attributed entirely to porosity.

Clear Creek calculated the average porosity for each borehole from the porosity values calculated from each 0.1-foot interval. Porosity was calculated only in the interval below the potentiometric surface; anomalous values recorded near the bottoms of the boreholes were also excluded. In some intervals the calculated porosity values were negative, due to anomalously high density (i.e., greater than 2.63 g/cc); the porosity values in these intervals were set to zero for purposes of calculating the average porosity for the borehole.

The results are shown on Table N-2. Average porosity values calculated for the boreholes ranged from 1.31% to 5.73%; the overall average (weighted to account for different borehole lengths) was 2.77%. Based on this result, a conservative 3% porosity was used to estimate the pore volume for the rinsing closure strategy (Attachment H-2).

4. CHANGES IN PRESSURE OF INJECTED FLUID

As presented in Attachment I, injection pressures will not exceed 0.75 pounds per square inch per foot (psi/ft). The maximum allowed injection pressures will vary from well to well, depending on the depth of the top of the injection interval. Therefore, maximum pressures will be calculated for each well using the pressure gradient of 0.75 psi/ft. Because the column of barren leach solution results in a pressure of approximately 0.45 psi/ft, filling the casing with barren leach solution will not exceed the 0.75 psi/ft limit recommended in this permit application.

Injection rates are expected to vary. Excelsior's preliminary production schedule anticipates injection rates to average 80 gpm, but may exceed 100 gpm. Actual rates will depend on the degree of fracturing, the transmissivity of fractures and the length of the injection zone. Heterogeneities within the leaching zone will result in some wells accepting more lixiviant than others. The groundwater flow model (Attachment A-2) uses an equivalent porous medium simulation to represent the aquifer system. Detailed information from Excelsior's geologic model has been incorporated into the model to represent faults as higher conductivity cells.

The overall injection rate of barren leach solution will be approximately equal to the total PLS recovery rate. On a more local scale, recovery rates will also be in approximate balance with the injection rates. Therefore, the area of influence of the injection wells will attenuate rapidly. Hydraulic control pumping will result in a net withdrawal of groundwater. This net withdrawal is a key element to maintaining control of the leaching solutions. As indicated by the groundwater flow model simulations in Attachment A-2, drawdown during the life of the Project generally remains less than 40 feet. Particle tracking simulations for particles released within the wellfield indicate that solutions stay within the wellfield or are captured by hydraulic control wells during the life of the Project. Particle tracking also indicates that there is not vertical migration to the sulfide zone beneath the injection zone. Aquifer testing (Attachment A-3) indicates that the sulfide zone has hydraulic conductivities approximately two orders of magnitude lower than the oxide zone.

5. NATIVE FLUID DISPLACEMENT

Figure N-6 is a regional potentiometric surface map. The figure shows that the direction of groundwater flow is from west to east. Hydraulic gradients vary considerably. East of the 4200-foot contour the gradient is relatively low. West of the 4200-foot contour, gradients are higher (approximately 0.15), which is consistent with the relatively unfractured nature of the Texas Canyon Quartz Monzonite. In the area of the deposit, the hydraulic gradient is much lower (0.01 and lower), due to the greater degree of fracturing, and thus higher permeability, associated with the oxide zone of skarn mineralization.

During injection and recovery in the wellfield, native fluid (i.e. groundwater) within the injection zone will be displaced by barren leach solution as the solution is injected. It will be displaced toward the recovery wells during the “conditioning” phase until the solution chemistry becomes consistent with PLS.

To the east of the wellfield, groundwater will be captured by the hydraulic control wells, as shown in Figures 60, 61, and 62 of the groundwater modeling report (Attachment A-2). The area of influence of the hydraulic control wells extends about 1000 feet to the east of the wellfield, even though simulated hydraulic pumping volumes (Table 12 of Attachment A-2) are generally less than 10 gpm.

6. DIRECTION OF MOVEMENT OF INJECTED FLUID

Advective flow of injected fluids will be governed by changes in pressure. Injected fluids will move from areas of high pressure (injection wells) to areas of low pressure (recovery and hydraulic control wells). The balanced injection and recovery rates simulated in the groundwater model will result in zero net pumping within the wellfield, and net withdrawal will be achieved by pumping of the hydraulic control wells.

According to the aquifer testing report (Attachment A-3), the oxide orebody has an average hydraulic conductivity of 1.1 feet per day (ft/day). The sulfide zone has a hydraulic conductivity of approximately 0.01 ft/day. Significant downward vertical migration of injected fluids is not expected, based on these aquifer parameters, nor was it seen during simulations in the model.

Figures 57 through 59 in Attachment A-2 show particle tracking during the life of mine operations. These figures show retention of particles within the wellfield or capture at hydraulic control wells. Figures 60, 61, and 62 in Attachment A-2 show velocity vectors and simulated heads for each layer simulated at the end of mining year 21, which is the year of maximum hydraulic control pumping. Upward flow vectors are red, downward flows are blue. While there are local areas of downward flow, the model showed that there was no flow downward into Layers 6 or 7, which are below the injection zone. These vectors also show containment.

TABLE N-1
Porosity Calculations from NSH-019 Aquifer Testing
Ramsahoye and Lang Method (1961)

Pumping Well	Symbol	NSH-019	Unit		Unit		Unit
Average Mobile Porosity	SY ¹					0.8	%
Test Discharge	Q	200,160	gpd	139	gpm		
Test Duration	t	5	days				
Test Volume	Q*t	1,000,800	gallons				
Transmissivity	T	1,353.88	gpd/ft	181	ft ² /d		

Observation Well	Unit	NSM-008	NSH-024	NSH-025	NSD-001	NSH-001	NSH-017	NSH-015	NSM-006	NSD-010	NSH-021C
Maximum Drawdown (s)	Feet	42.6	18	17	13	9.3	14.2	7.3	11.8	4.9	60.4
Distance to Pump (r)	Feet	76.8	223.6	277.8	362.1	445.9	500	626.5	639.7	1493	70.7
Aquifer Volume	Feet Cubed	8,147,371	8,533,788	12,098,965	14,631,294	16,200,073	30,893,216	26,980,822	41,236,424	124,950,449	31,348,163
Estimated Minimum Porosity	Percent	1.6	1.6	1.1	0.9	0.8	0.4	0.5	0.3	0.1	0.4

Notes:

¹ SY estimated as test volume divided by aquifer volume

SY = specific yield

Q = flow

t = time

gpd = gallons per day

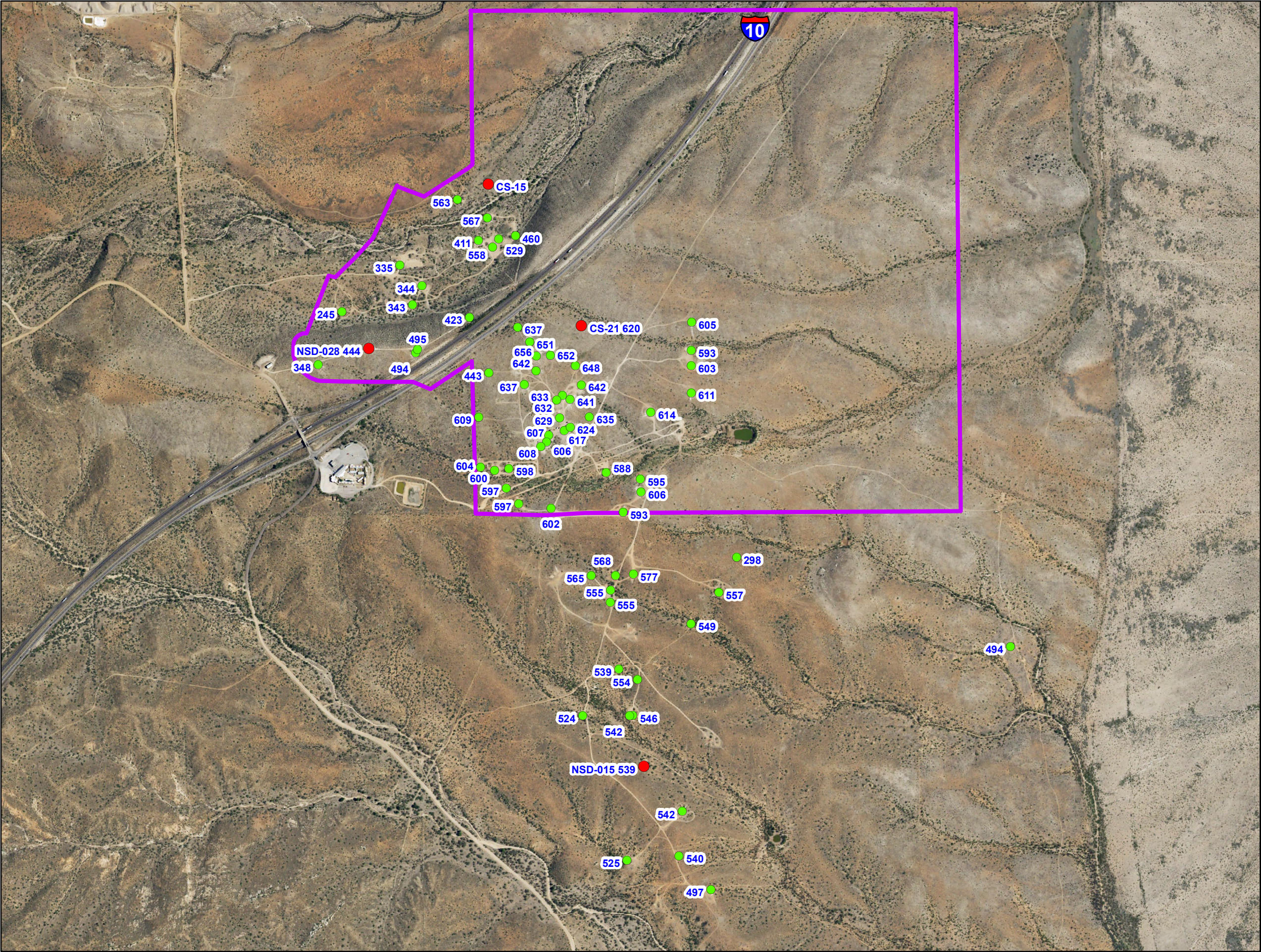
gpd/ft = gallons per day per foot

gpm = gallons per minute

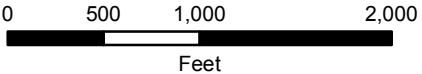
ft²/d = feet squared per day

TABLE N-2
Porosity from Gamma-Gamma Logs

Well	Average Porosity of Borehole (%)	Zone of Analysis (feet)	Length of Zone of Analysis (feet)	Weight % of Borehole	Average Porosity Multiplied by Weight of Borehole
NSH-008	3.46	347-890	543	19%	0.65
NSH-009	1.99	561-1041	480	17%	0.33
NSH-013	2.66	698-1069	371	13%	0.34
NSH-015	2.11	592-815	223	8%	0.16
NSH-023	2.69	646-1440	794	27%	0.74
NSH-28	5.73	586-800	214	7%	0.42
NSH-026	1.31	630-897	267	9%	0.12
	Average Porosity % Unweighted 2.85		Total Length of Borehole Analyzed 2,892		Porosity % Weighted Average 2.77



- Legend**
- Gunnison Copper Project
 - Well showing depth to groundwater (feet below land surface)
 - Well showing depth to groundwater, if available (feet below land surface) and Hydrograph Location

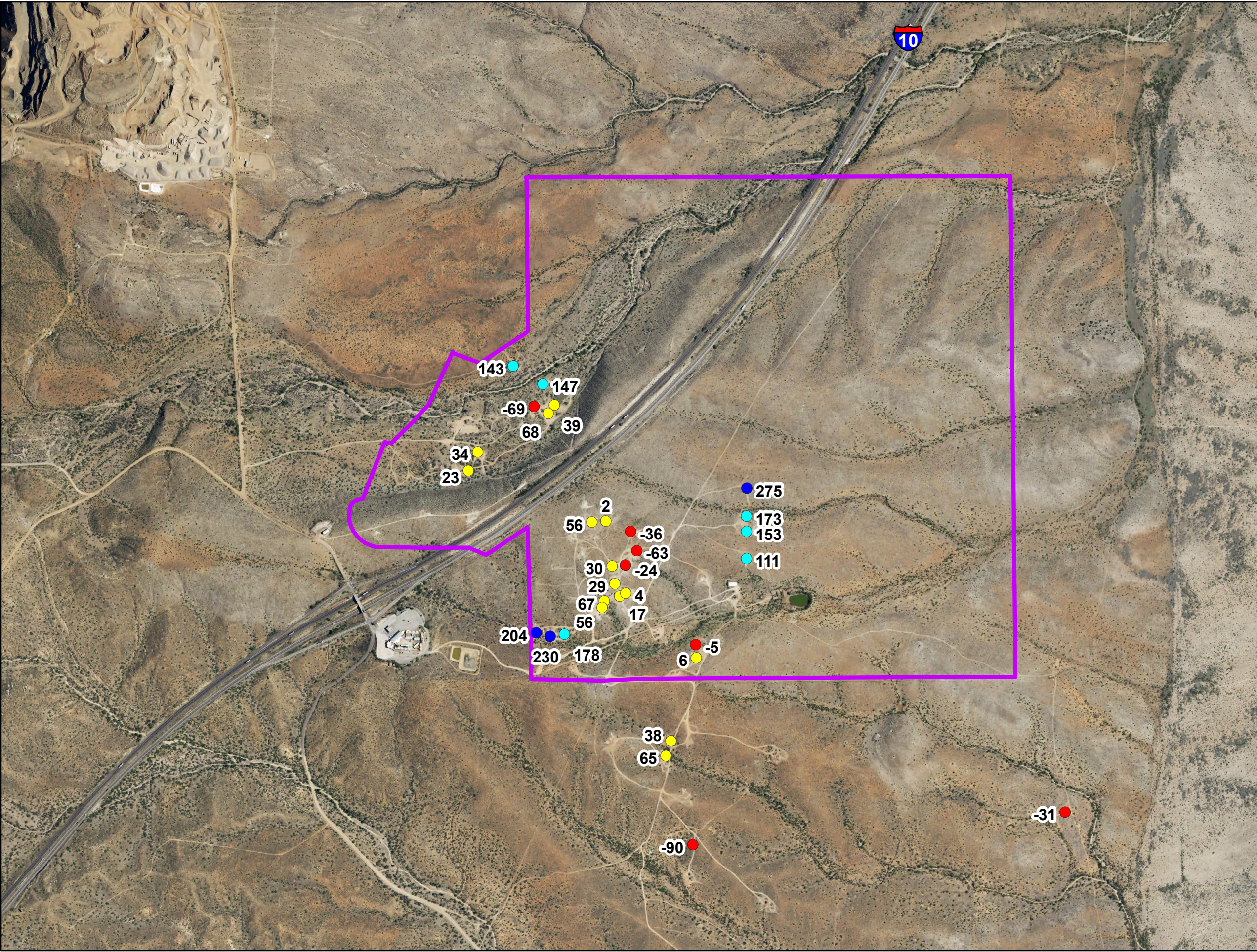


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Gunnison Copper Project
UIC Permit Application
February 2016

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FIGURE N-1
Depths to Groundwater,
June 2015



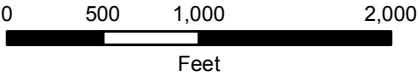
Legend

Gunnison Copper Project

NSH Well - Bedrock - Water Depth

- 90 - 0
- 1 - 100
- 101 - 200
- 201 - 300

Value shown is the difference between the bedrock depth (feet) and the potentiometric surface (ft bls). Positive numbers indicate the potentiometric surface is deeper than the bedrock-basin fill contact. Negative numbers indicate the potentiometric surface is above the basin fill-alluvium contact. Most negative numbers are indicative of confined conditions, not saturated alluvium.

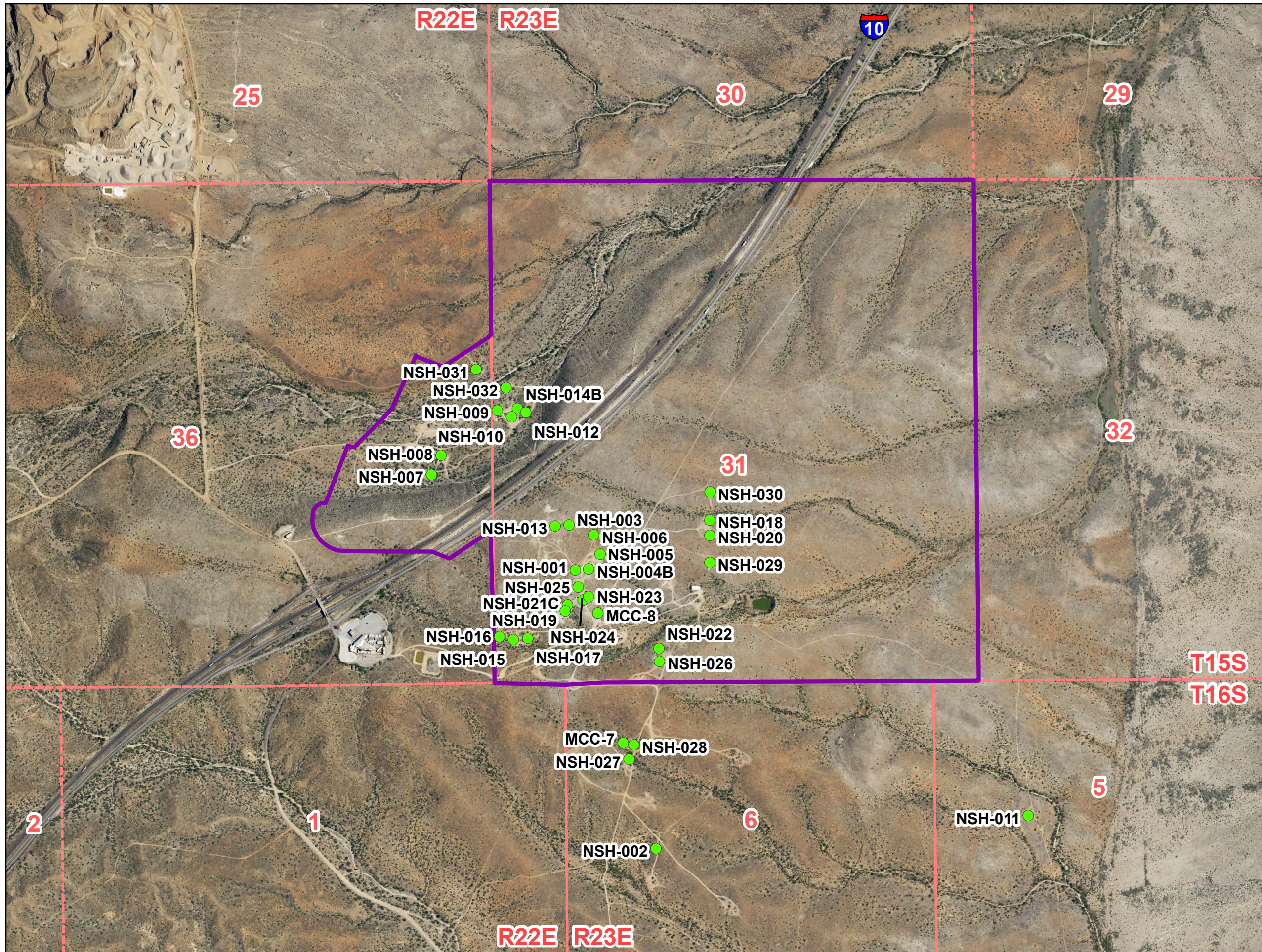




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Gunnison Copper Project
UIC Permit Application
February 2016

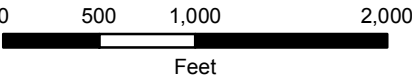
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FIGURE N-2
Potentiometric Surface
in Relation to Bedrock



- Legend**
-  Gunnison Copper Project
 -  Hydrology Study Borehole or Well

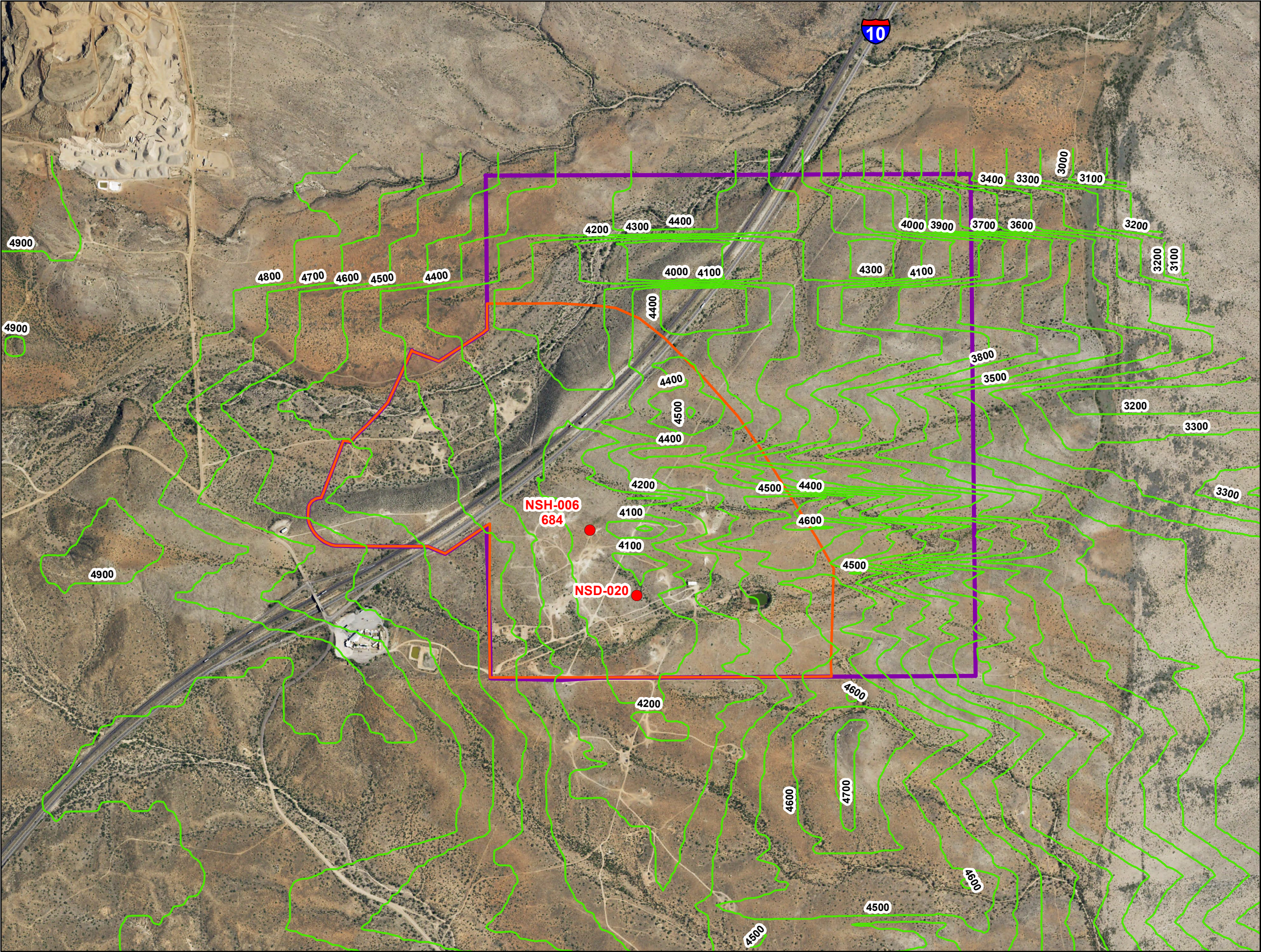


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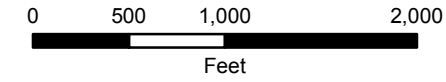


FIGURE N-3
Hydrology Study
Boreholes and Wells



- Legend**
- Gunnison Copper Project
 - Area of Review
 - Bedrock Surface Elevation Contour (100 ft interval)
 - Well with Saturated Basin Fill (showing bedrock depth where known)

Source:
Excelsior Geologic Model

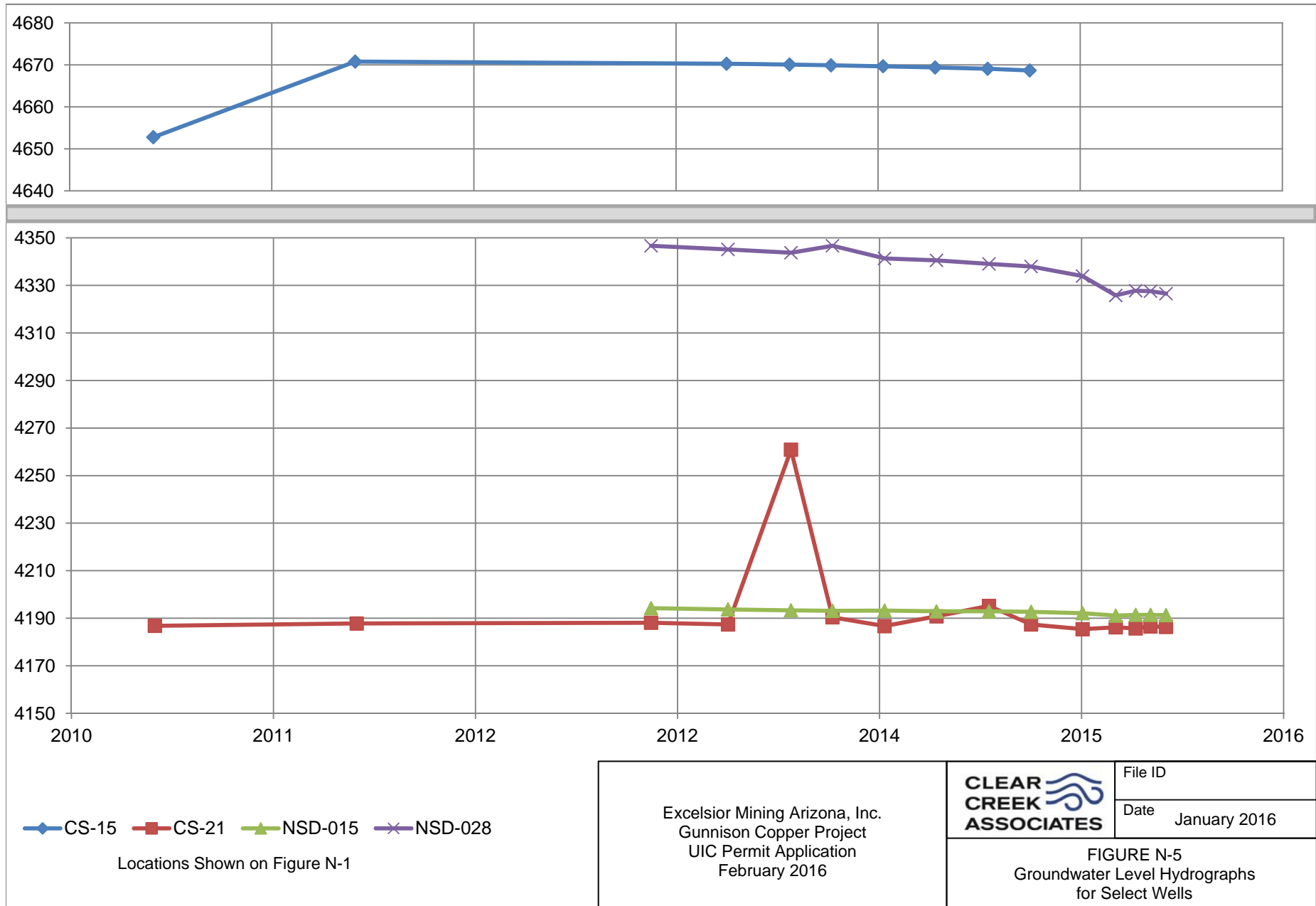


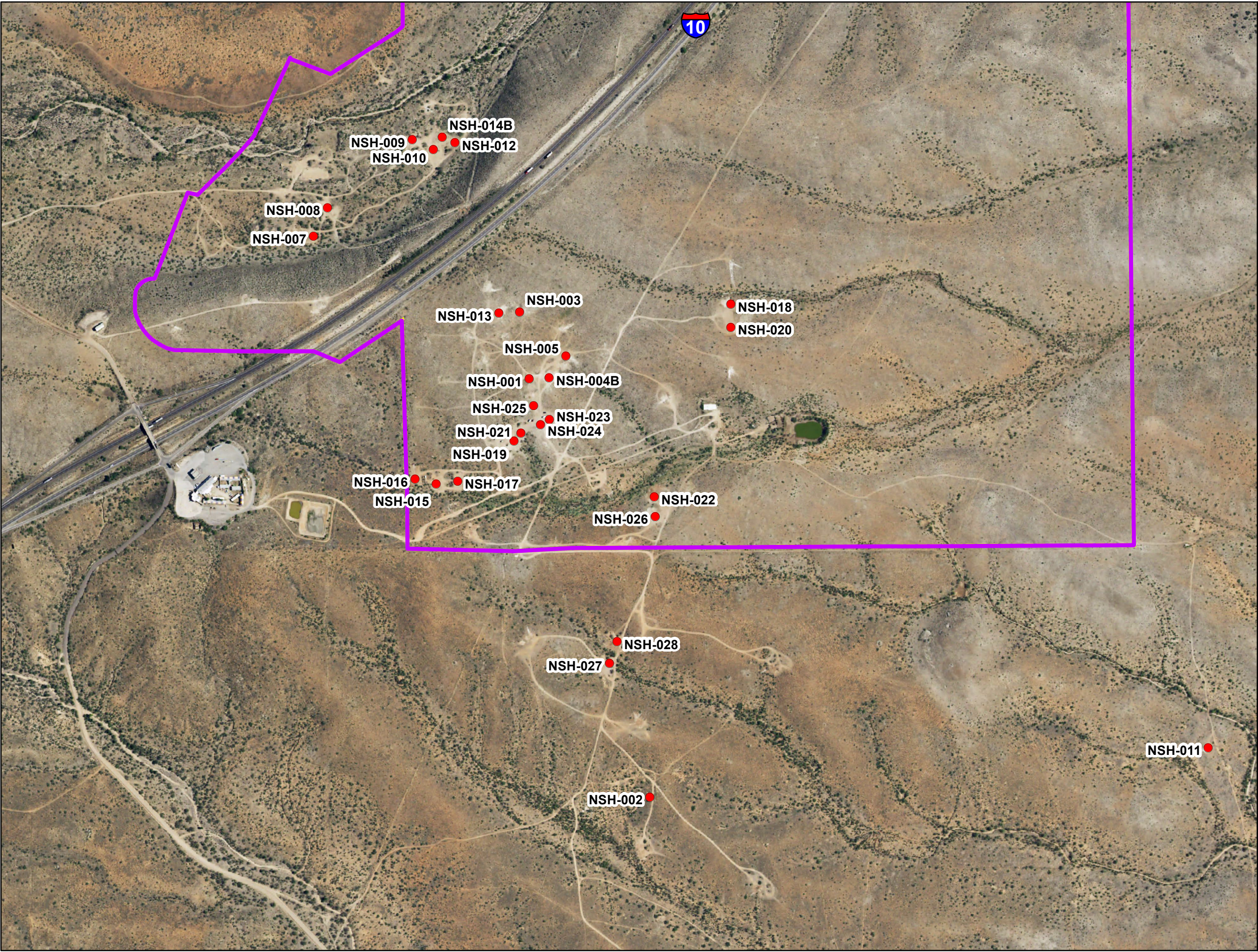
Excelsior Mining Arizona, Inc.
Gunnison Copper Project
UIC Permit Application
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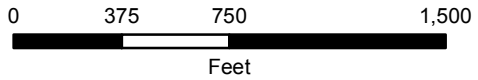
**CLEAR
CREEK
ASSOCIATES**

FIGURE N-4
Bedrock Elevation Contours





- Legend**
-  Gunnison Copper Project
 -  NSH Well Where Aquifer Testing was Conducted



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February 2016

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FIGURE N-7
Aquifer Testing Locations